

BNL Advanced Accelerator Group

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Brookhaven National Laboratory
DOE HEP Site Visit
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Group Focus

- Design and simulations of accelerators based on muon beams
 - Neutrino factory
 - Muon collider
- Technologies useful for these and other machines
 - Liquid Hg jet target
 - High gradient RF cavities
 - Fixed field alternating gradient accelerators

Personnel and Collaborators

- 5 staff members (Berg, Fernow, Gallardo, Kirk, Palmer)
- 1 postdoc (Stratakis)
- Visiting collaborators
 - X. Ding (Postdoc, UCLA)
 - S. Kahn (Muons Inc.)
 - J. Lederman (Student, UCLA)
 - K. McDonald (Princeton)
 - H. Park (Student, Stony Brook)

Collaboration: Short-Term Visitors

- A. Garren (Particle Beam Lasers)
- F. Méot (IN2P3 Grenoble)
- G. Prior (CERN)

Participation in Collaborations

- NFMCC/MCTF
- International Design Study of the Neutrino Factory (IDS-NF)
- Several experiments
 - ▣ EMMA (Non-Scaling FFAG, Daresbury)
 - ▣ MERIT (Hg jet target, CERN)
 - ▣ MuCool (RF Cavity Testing, Fermilab)

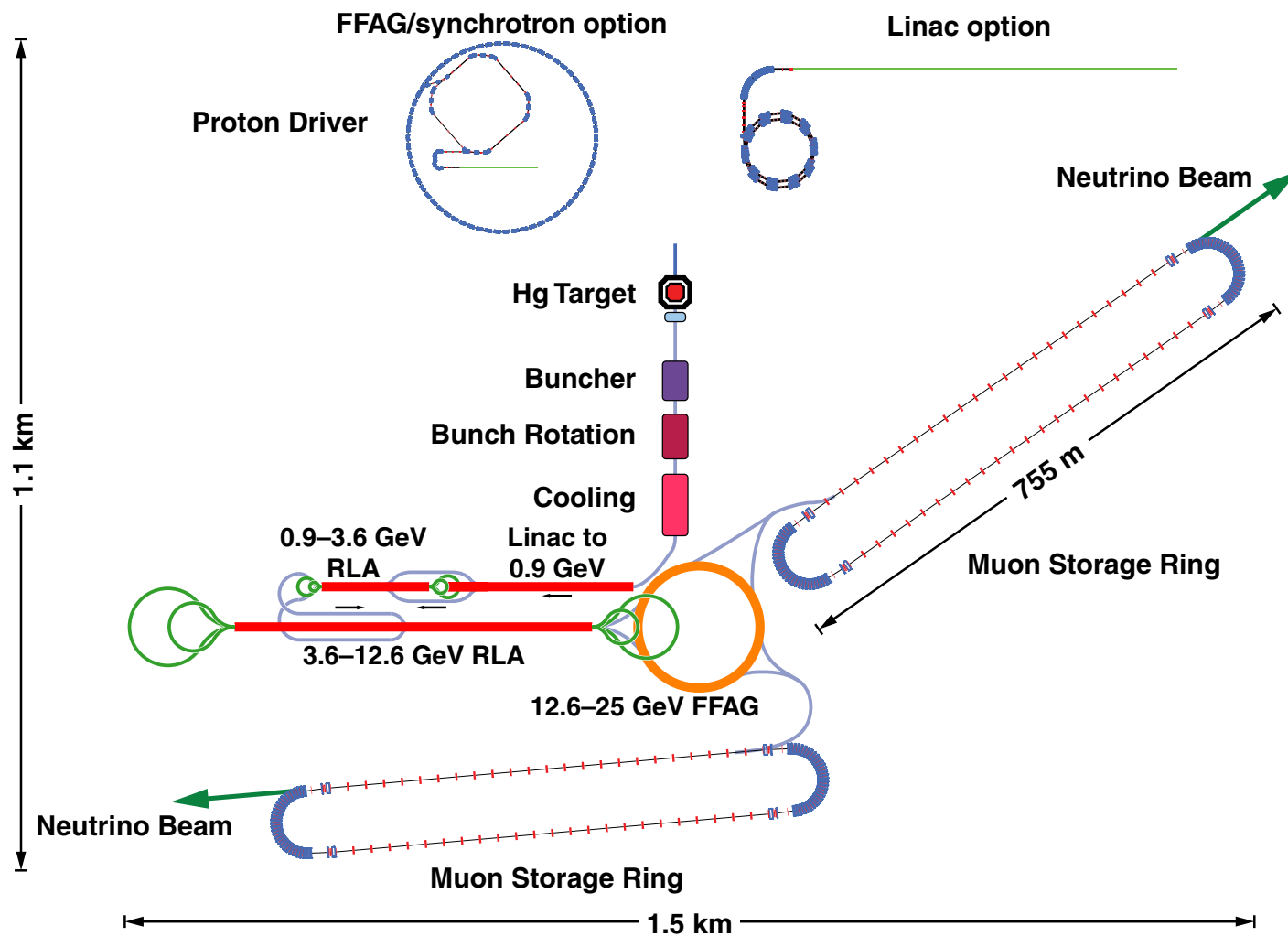
Talks at Particle Accelerator Conference

- Several talks given by us or where we were significant contributors
- Muon Collider (invited, Palmer)
- MERIT (invited, McDonald)
- EMMA (invited, Smith)
- FFAG for IDS-NF (contributed, Berg)
- Tomography (contributed, Stratakis, earlier work)

Neutrino Factory

- Accelerate muons to high energy
- Decay in storage ring toward far detector
- Well-known neutrino flux
- Only way to measure some quantities at smallest θ_{13}
- High-precision measurements
- Probe new physics

IDS-NF Baseline



International Design Study of the Neutrino Factory

- Goal: produce a design report for a neutrino factory by 2012
- Our involvement
 - Leading the accelerator portion of the effort
 - Design of the target system
 - Design of part of the acceleration system (FFAG)

Muon Collider

- Potential energy frontier (3 TeV CoM) machine
- Use of muons
 - Point-like particles
 - Unlike electrons, can be bent
 - ✧ Efficient acceleration
 - ✧ Multiple collisions
 - Enhanced cross-section for s -channel processes

Muon Collider

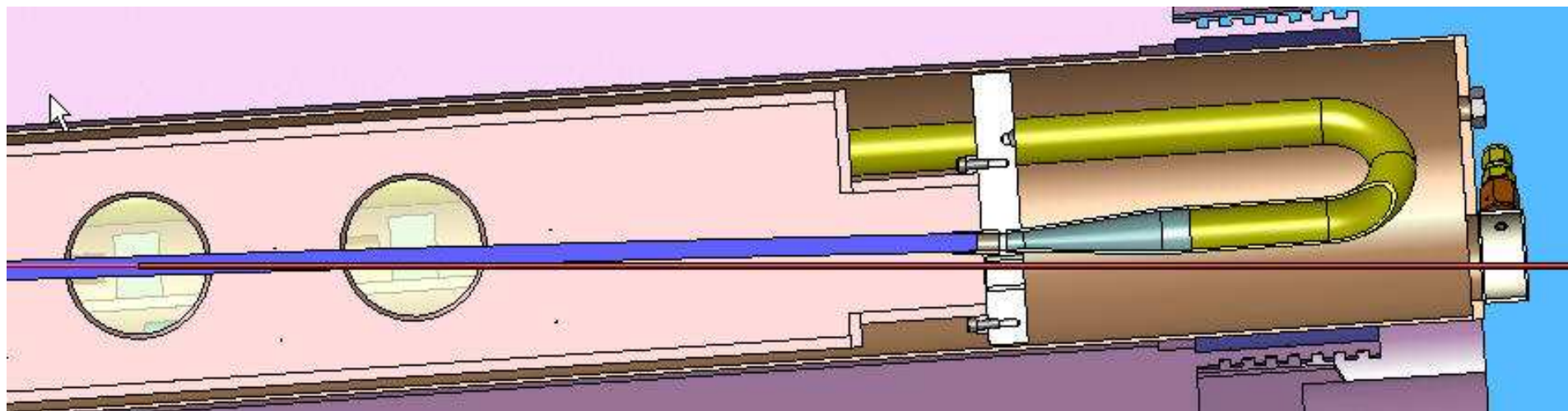
5-Year Plan

- “5-Year Plan”
 - National effort
 - Plan to increase effort to achieve a muon collider design
 - We made significant contribution to writing plan
- Our muon collider work
 - Cooling simulation efforts
 - Acceleration system design

Target Studies

MERIT Experiment

- High power targets useful for many accelerator applications
- Liquid jet targets address target breakage
- MERIT experiment: liquid mercury jet target

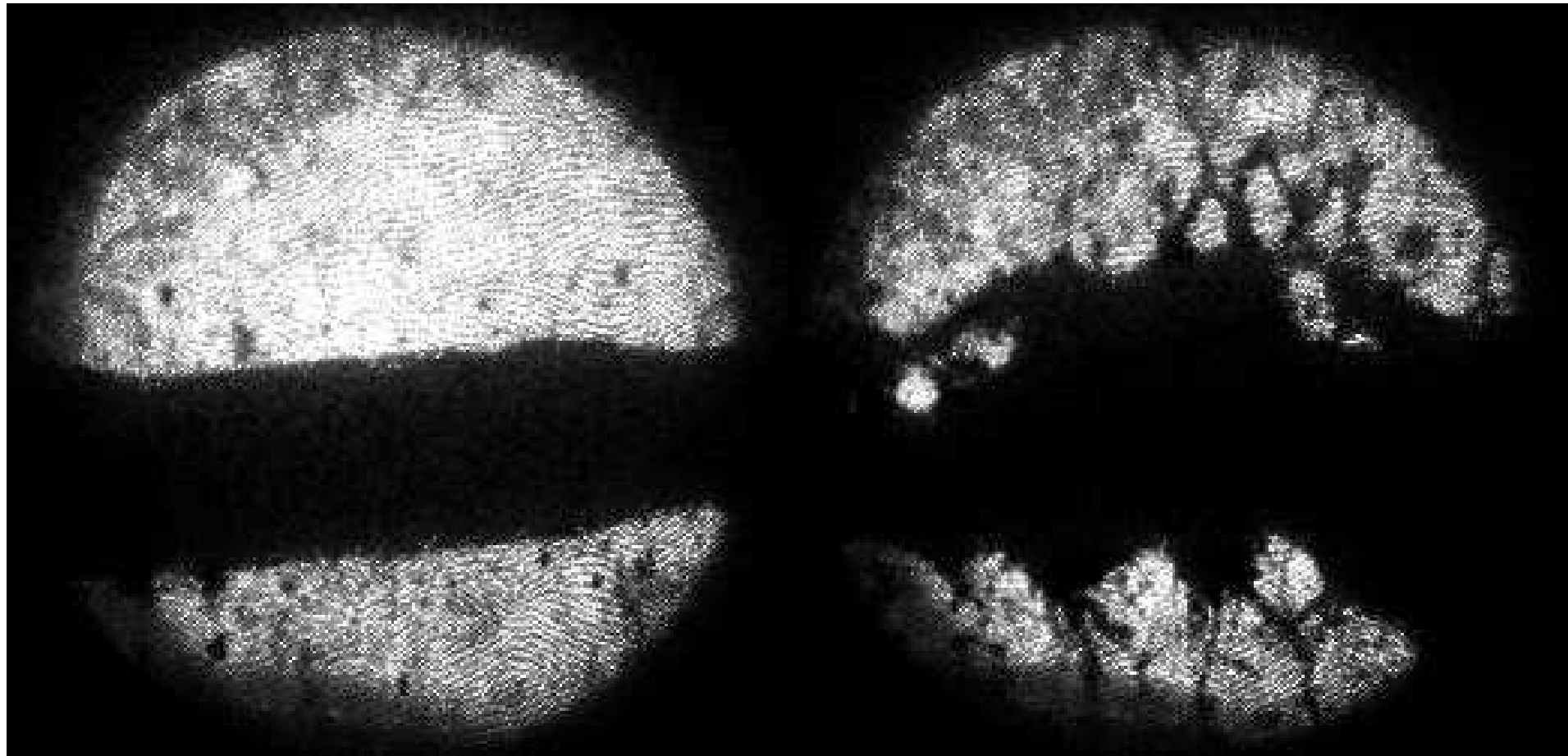


Target Studies

MERIT Analysis

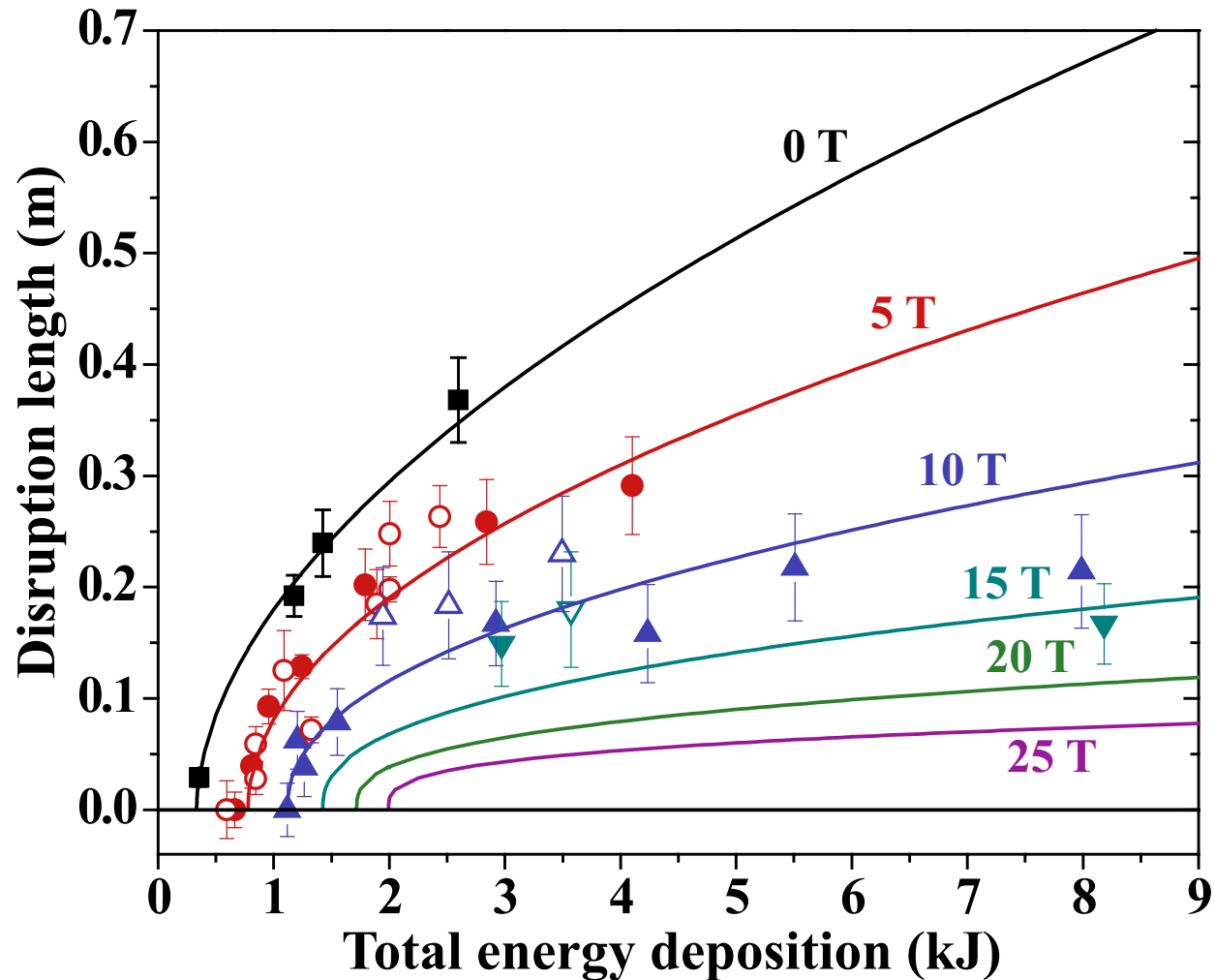
- Disruption by jet of proton beam pulse
 - No disruption below threshold pulse energy
 - Threshold increases with B field on jet
 - Pulses act like separate below-threshold pulses with sufficient separation
- Disrupted jet: production from second pulse not reduced for at least $350 \mu\text{s}$ after first
 - Good for neutrino factory proton driver

MERIT Experiment Jet Disruption



MERIT Experiment

Disruption vs. Pulse Energy and B



Target Studies

Target Production Studies

- Motivation: find optimal proton driver energy
- Production per unit power vs. proton energy
- Optimize target geometry for each energy
 - ▣ Strongly peaked from 5–10 GeV
 - ▣ Prioritized HARP data analysis at low energy
 - ✧ Not consistent with this result
 - ✧ New model going into MARS now...
- Begin studying effects of beam divergence

Fixed Field Alternating Gradient Accelerators (FFAGs)

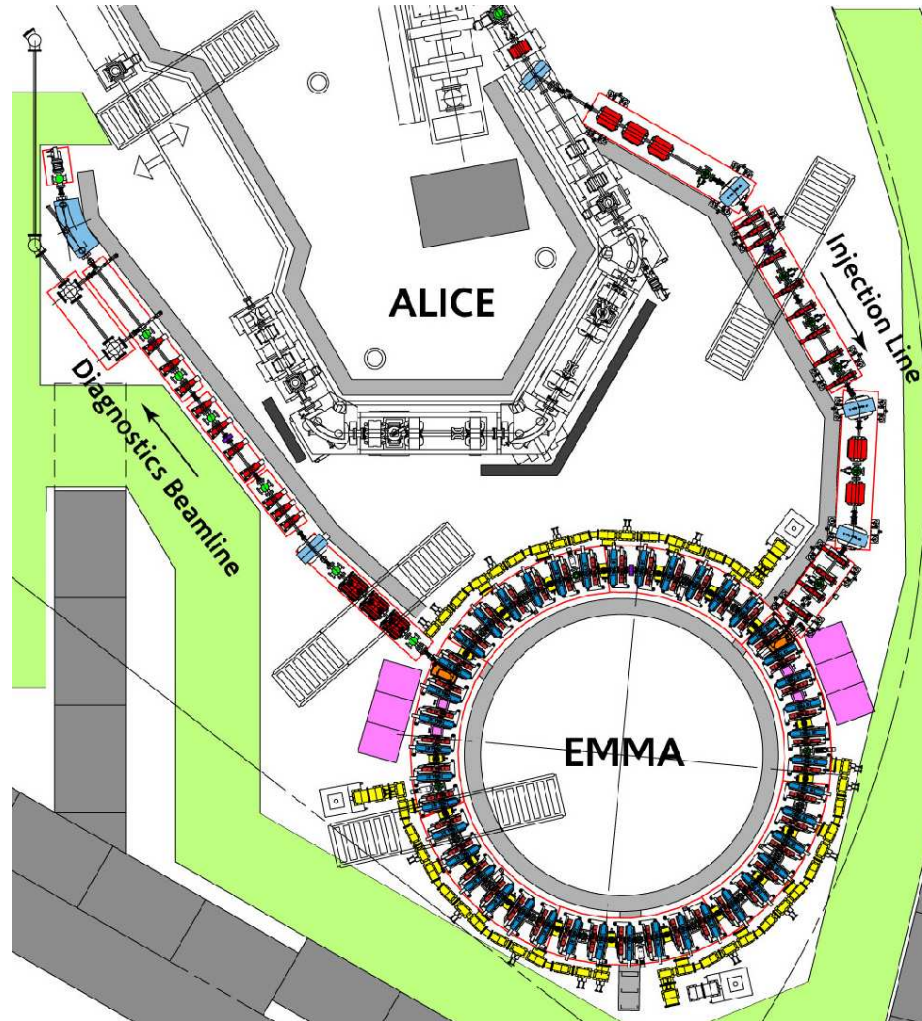
- Muon advantage: recirculate through accelerating cavities
- Must accelerate rapidly
- No time to ramp magnets (low energy)
- Fixed field alternating gradient accelerators
- Use “non-scaling” design to reduce aperture/cost
- Lattice design for IDS-NF

FFAGs

EMMA Experiment

- FFAGs useful in many applications, but no non-scaling FFAG has ever been built
- EMMA Experiment at Daresbury Laboratory
- Due to have beam at end of year
- Our contributions
 - Specification of experiments
 - Design of main ring
 - Injection/extraction beam dynamics
 - Accelerator physics input

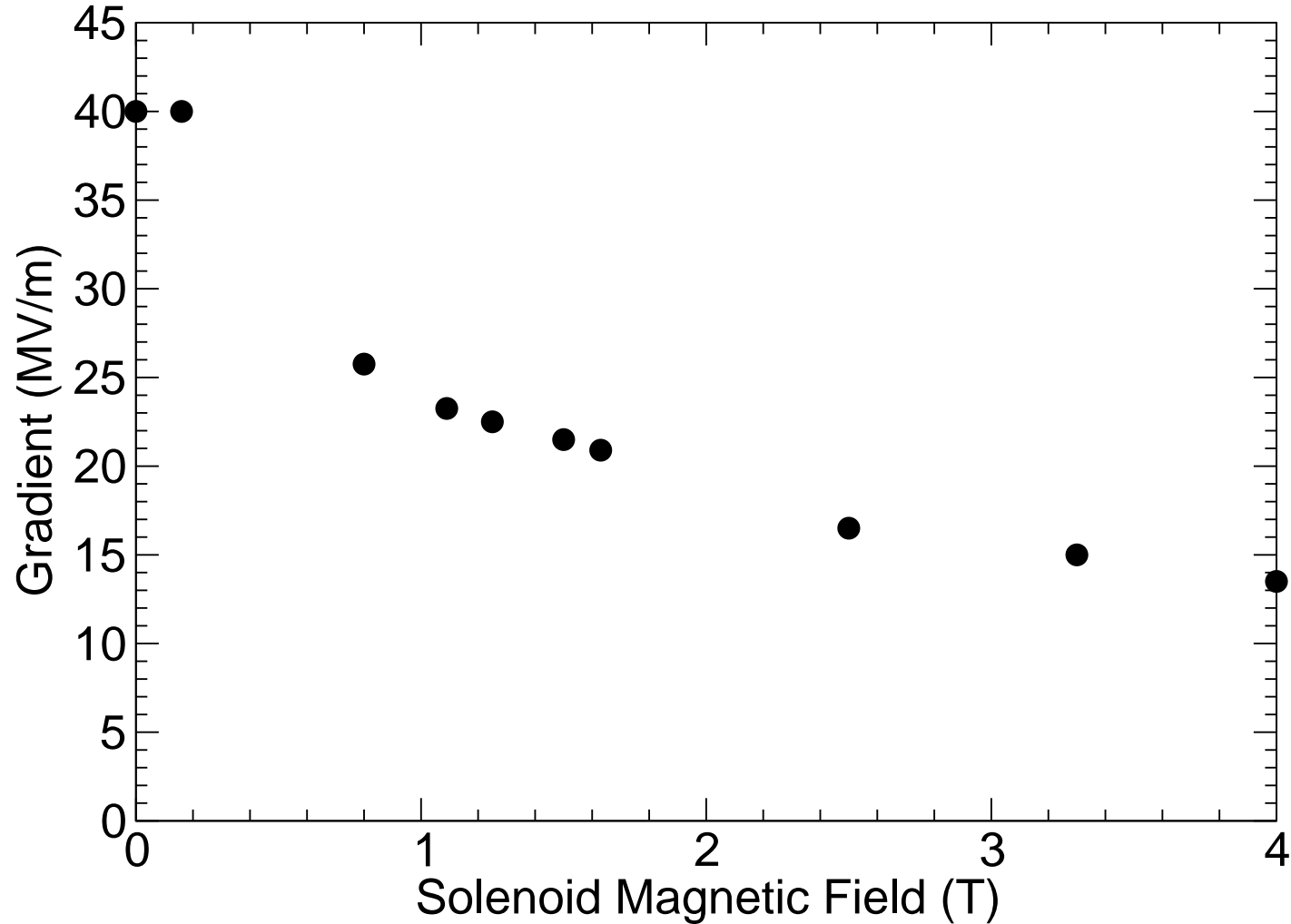
EMMA Experiment



Breakdown in RF Cavities

- Ionization cooling channels have RF cavities near high magnetic fields
- Logarithmic cooling rate proportional to RF gradient
- High magnetic fields reduce multiple scattering
- Experimental results: RF gradients reduced in presence of magnetic fields
- Potentially significant limitation on cooling channel performance

Experiments: RF Gradient in Magnetic Field



Breakdown in RF Cavities

Our Activities

- Understanding RF breakdown of wide interest
- Develop theory of RF breakdown in magnetic fields
- Simulate electron motion in cavities
- Develop mitigation strategies
- Propose experimental tests

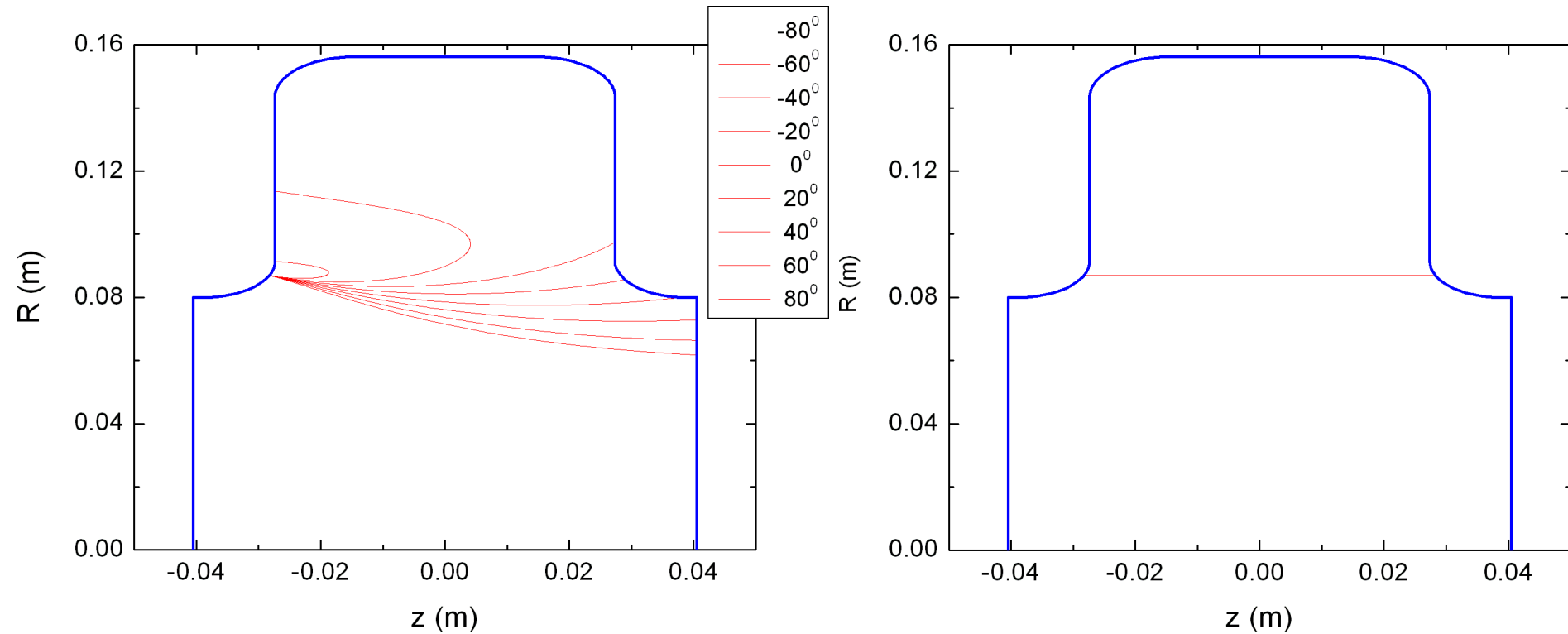
Breakdown in RF Cavities

Our Theory

- Based on our analysis of experimental evidence
- Field emission at asperities
- Magnetic fields focus emitted electrons
- Destination surface is heated, fatigues
- New damaged surface breaks down easily

Breakdown in RF Cavities

Electron Beam Focusing



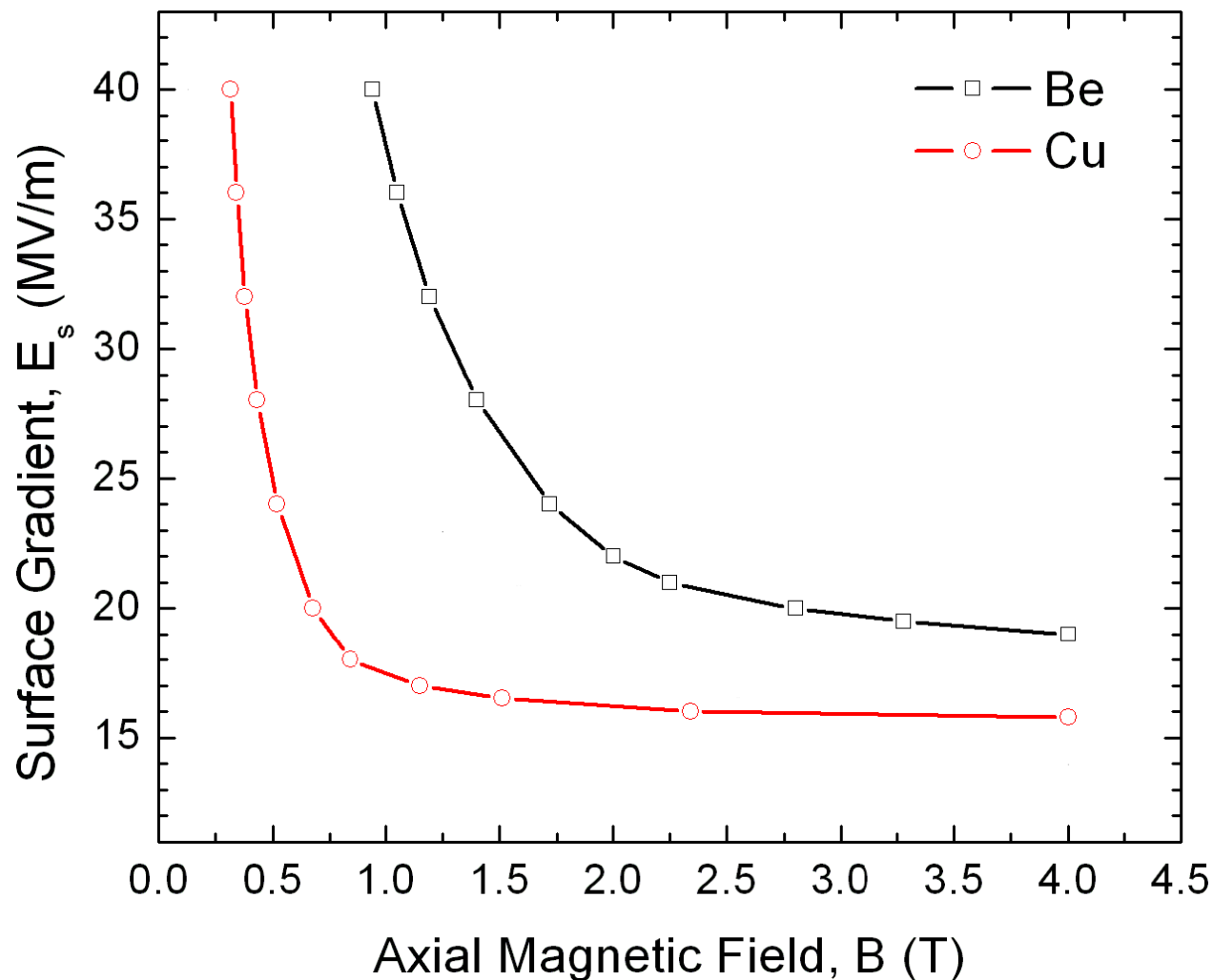
Breakdown in RF Cavities

Our Studies

- CAVEL, BNL code to track electrons in cavities
 - Determine energy and trajectory of emitted electrons
 - Calculation is rapid, allows scanning over RF phase, surface location
- PARMELA simulations: space charge
 - Determine spot size of emitted electrons
 - Slow, cylindrically symmetric
- Simulate heat conduction in cavity wall

Breakdown in RF Cavities

Simulation Results



Breakdown in RF Cavities

Possible Mitigations

- Magnetic insulation
 - Cavity surfaces parallel to B field lines
 - Emitted electrons can't gain energy
- Construct cavity from beryllium
 - Electrons penetrate further
 - Higher yield strength
- High-pressure gas in cavity
 - Inhibits electron propagation

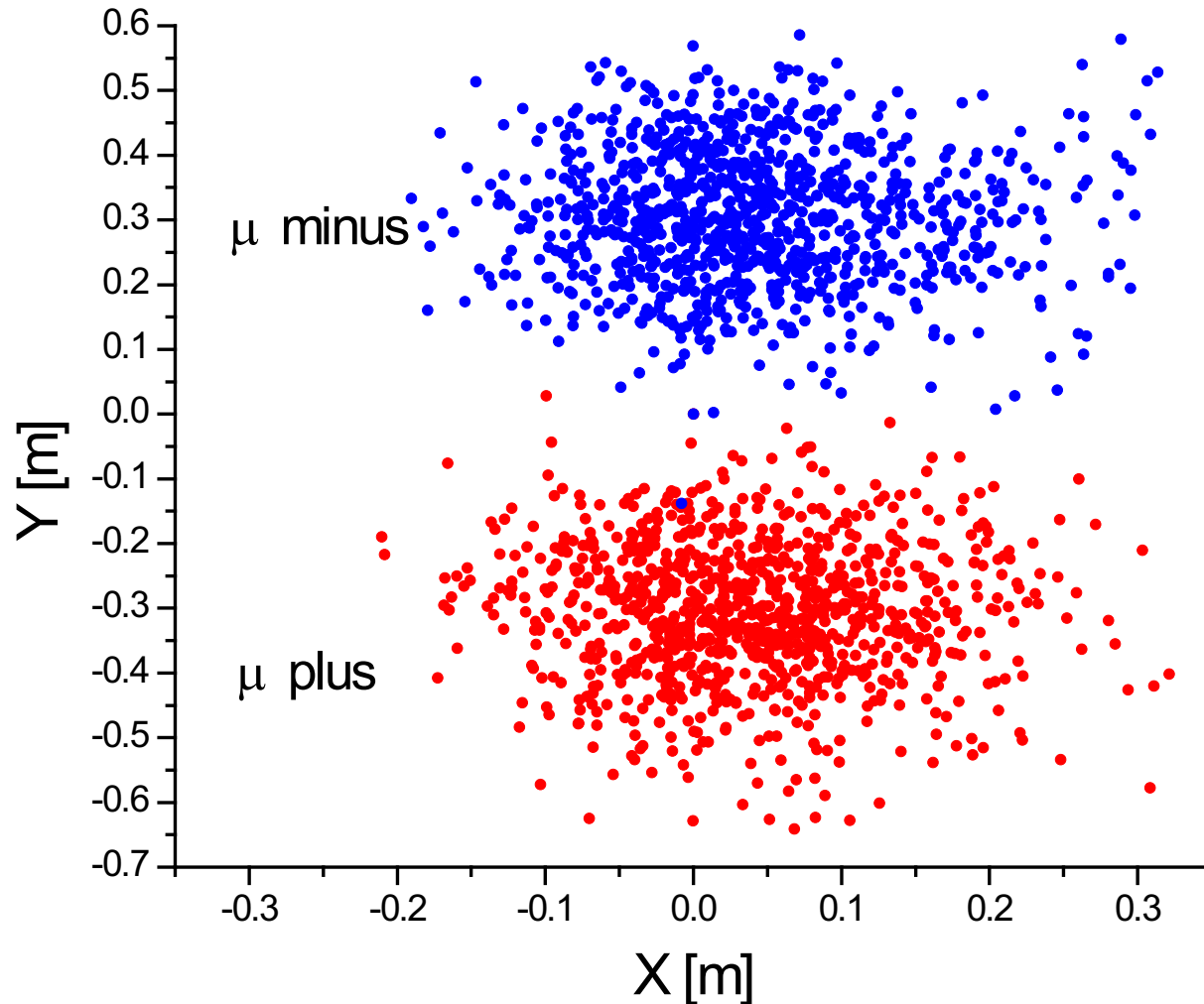
Breakdown in RF Cavities Experiments

- Our theories have led to experimental proposals
- Experiment at Fermilab with E and B perpendicular
- Collaboration with PBL (SBIR) to design magnetically insulated cavity and cooling lattice
- Cavity tests with field enhanced at Be and Cu buttons
- Beryllium cavity

Cooling Lattice Studies

- Muon collider cooling: only one charge
- Must separate charges
- Studied charge separation for muon collider
 - Several techniques
 - Bent solenoid worked best
- Simulated magnetically insulated cooling lattice
- Simulated existing channel with absorbers replaced by gas

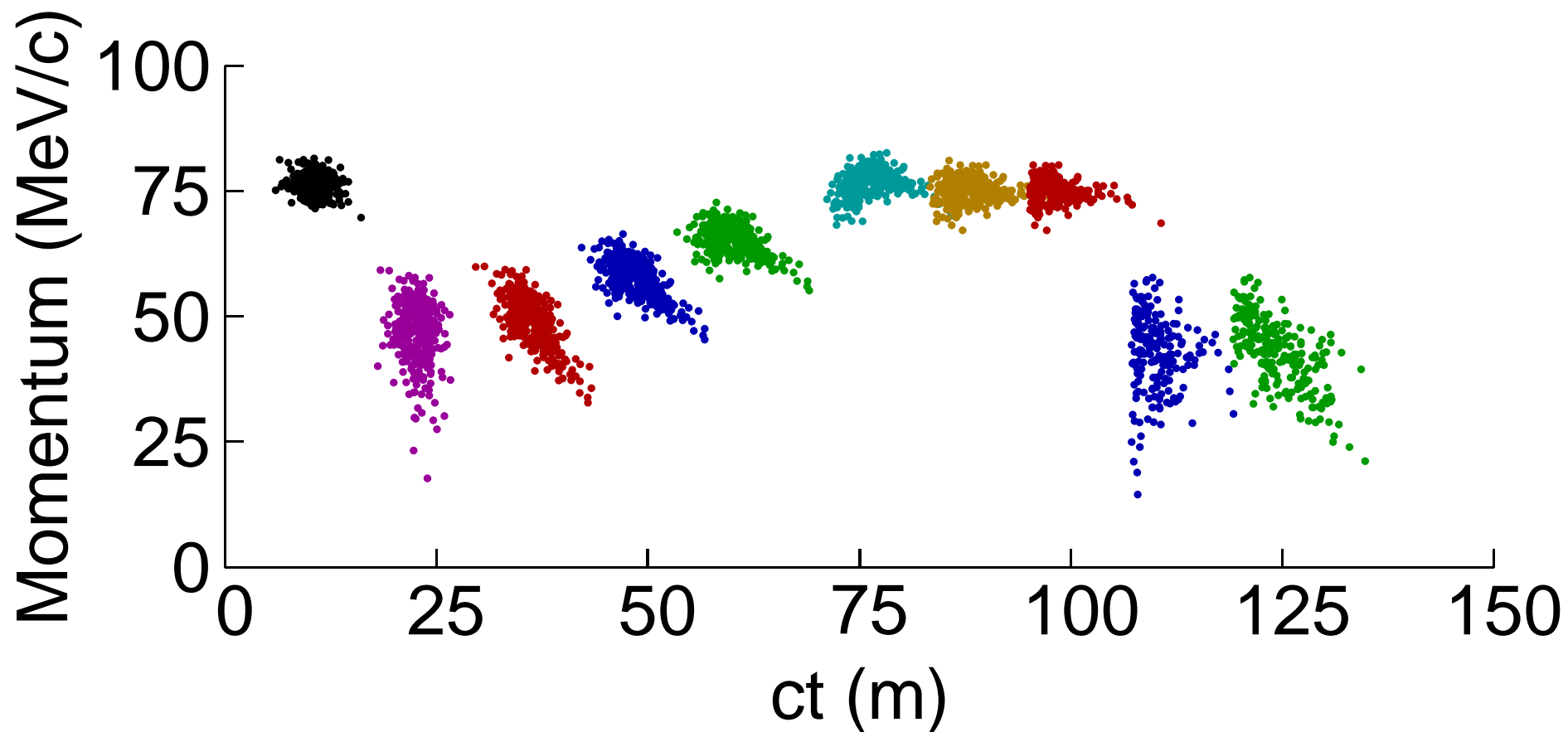
Muon Collider Charge Separation



Cooling Lattice Studies

- Cooling to final emittance
- Designed system requiring high-field (40–50 T) solenoids
- Motivated two SBIR grants to PBL for high-field solenoid design, collaborating with BNL magnet division

Cooling to Final Emittance



Future Priorities

- Improve understanding of RF breakdown
- Participate in RF breakdown experiments
- Cooling lattices compatible with RF constraints
- Complete cooling system for muon collider
- Participate in EMMA experiment
- IDS-NF FFAG and target design
- Finish MERIT analysis
- FFAG techniques for muon collider acceleration

Personnel Needs

- Leverage existing expertise in group
- Need more manpower to complete tasks
- Priorities for new personnel
 - Apply accelerator theory techniques to improve cooling lattice design
 - Design of full cooling system, especially transitions, tapering, matching
 - FFAG-like muon collider acceleration